



# Investigating representations of indigenous peoples and indigenous knowledge in zoos

Jonathan Robert Bowers <sup>1\*</sup> , Gail Richmond <sup>1</sup> 

<sup>1</sup>Michigan State University, East Lansing, MI, USA

\*Corresponding Author: [bowersj8@msu.edu](mailto:bowersj8@msu.edu)

**Citation:** Bowers, J. R., & Richmond, G. (2023). Investigating representations of indigenous peoples and indigenous knowledge in zoos. *Interdisciplinary Journal of Environmental and Science Education*, 19(4), e2321. <https://doi.org/10.29333/ijese/13746>

## ARTICLE INFO

Received: 03 Jul. 2023

Accepted: 04 Sep. 2023

## ABSTRACT

Many scholars advocate for indigenous knowledge (IK) to be integrated into science education to foster a more inclusive educational environment. Informal science learning spaces provide opportunities for encountering science phenomena and broader perspectives. Zoos have the potential to include IK into their informational signage due to having collections of native plants and animals that are significant to Indigenous communities. The history of zoos being platforms for colonialist ideologies also necessitates acknowledgement of how White Settler colonialism has negatively impacted Indigenous peoples. We therefore investigated how two zoos in North America portray IK and perspectives in zoo sections centering native animals. We found that while both zoos provide strong examples of how IK can be included in zoo signage, certain aspects of IK (particularly that of climate patterns), were largely absent. Additionally, zoo signage largely ignored the impact of settler colonialism on both the natural environment and indigenous cultures.

**Keywords:** indigenous knowledge, informal science education, zoos, settler colonialism

## INTRODUCTION

Recent controversies and tragedies such as the discovery of mass graves of children at the Kamloops Residential School have reignited discussions on Indigenous rights (Bardon, 2022; Dickson & Watson, 2021; Larocque et al., 2021; McKenzie, 2021; Mengden, 2017). Additionally, the Land Back movement is seeking the restoration of indigenous sovereignty and advocating for fundamental changes in land stewardship to promote a more sustainable future (Pieratos et al., 2021). Alongside this broader reckoning, the educational community has continued to explore the impact of White Settler colonialism on indigenous education. While some seek to bring light to the horrors of the residential school systems (Adams, 1995; Cassidy, 2006; MacDonald & Hudson, 2012; Rosalyn, 1991); other researchers have sought to protect and restore indigenous knowledge (IK) and understandings (Lowan, 2012; McKinley, 1996; Quigley, 2009; Snively & Corsiglia, 2001). Within science education a growing number of scholars seek to reimagine science in a way that celebrates Indigenous epistemologies and contributions to our collective understanding of the natural world (Kim et al., 2017; Ogawa, 1995; Snively & Corsiglia, 2001; Zidny et al., 2020). These scholars recognize the detrimental impact and limitations of western modern science (WMS) and argue that including Indigenous ways of knowing is beneficial for student learning

and for scientific advancement (Kim et al., 2017; Ogawa, 1995; Munroe et al., 2013; Quigley, 2009; Singleton et al., 2021). As such they have begun to consider how IK can be included in both K-12 education and in informal learning spaces, such as museums and afterschool programs (Aikenhead & Elliott, 2010; Brayboy & Castagano, 2008; Lowan, 2012; Marin & Bang, 2015; Munroe et al., 2013; McKinley, 1996).

Informal science learning spaces can play a vital role in supporting the efforts of formal K-12 education. As K-12 classrooms are often constrained by the demands of state and national educational standards, informal learning spaces can therefore provide opportunities for students to explore and discuss aspects of science (including IK) that might otherwise be absent from their K-12 experience (Aikenhead et al., 2001; Goodwin, 2016). They also can offer students opportunities to explore different phenomena (Rennie & McClafferty, 1995; Schwan et al., 2014). For example, students can get a more holistic view of orbital mechanics at a planetarium, observe carnivorous plants at a conservatory, or listen to bird songs at a nature preserve. Finally, informal learning spaces often allow for more student-led exploration and are generally less structured than traditional K-12 learning environments (Bonnette et al., 2019; Dunlop et al., 2019). This less structured environment allows for more student-directed learning and student choice, which have been shown to boost student socio-emotional engagement and strengthen student science identity (Bonnette et al., 2019; Dunlop et al., 2019; Kress &

Elias, 2019). Given this potential to bolster student learning, recent policy documents and empirical studies highly recommend that teachers make use of informal learning experiences (Adams & McCullough, 2021; Miyake, 2017; NRC, 2012; Tang & Zhang, 2020).

One informal science learning space that has the potential to integrate IK into science education and can reach a broader audience are zoos. Contemporary zoos often serve as a conduit for biology and conservation education for a mass audience (Ballantyne & Packer, 2016; Nygren & Ojalampi, 2018; Packer & Ballantyne, 2010). As an informal science learning space, zoos provide an important opportunity for students to experience scientific phenomena in a manner not possible in traditional K-12 settings (Clifford-Clarke et al., 2022; Meiers, 2010; Pace & Tesi, 2004; Schwan et al., 2014). While visiting zoos, children can participate in self-directed learning as they observe animal species, watch zookeeper-led demonstrations, and read informal signs associated with each exhibit. Zoos also often offer outreach programs to K-12 student groups, which allow students to receive supplemental instruction from zoo staff. These experiences can then be used by their classroom teachers to spark further discussion on conservation and ecology-related topics (Meiers, 2010). Because zoos are an important center of informal science learning and hold great potential to accomplish the goals of contemporary science education reform, zoos have a responsibility to be an inclusive space for all learners. Such inclusivity can include incorporating IK to support learners from indigenous communities.

Many zoos feature plants and animals that have historical, cultural, and/or ecological significance to Indigenous communities (Barsh & Marlor, 2003; Gagnon & Berteaux, 2009; Posthumus, 2016; Wehi et al., 2019). Such exhibits offer opportunities to share IK to a broader audience, which can enhance the quality of the science being presented. Many indigenous knowledge systems (IKS) place humanity in relationship with the natural world and emphasize our responsibilities to other organisms (Aikenhead & Ogawa, 2007; Bang et al., 2007; Brayboy & Castagano, 2008). This more holistic view of ecology contrasts with the anthropocentrism and reductivism that often pervades western views of science (Aikenhead & Ogawa, 2007; Enslin & Horsthemke, 2015). Due to their long histories of co-existing with their local environments, Indigenous communities often have deep knowledge of the climate history of their homelands and are often uniquely vulnerable to climate change (Ford et al., 2016; Maldonado et al., 2016; Nakashima & Krupnik, 2018). Therefore, including both historical and contemporaneous accounts of how Indigenous people interact with a changing climate can provide a unique opportunity to discuss the human impact of climate change.

Additionally, many conservation narratives are incomplete without reflecting on the relationship between native species and Indigenous cultures. For example, many indigenous societies (including the Lakota) depended on the American Bison for their survival (Barsh & Marlor, 2003; Hamalainen, 2019; Posthumus, 2016). In their efforts to exterminate native Americans, the US railroad companies and military officials deliberately targeted bison herds for mass slaughter to force indigenous societies onto reservations (Barnard, 2020; Eichler,

2020; Hubbard, 2014). As with the bison and the Lakota, White Settler colonialism was responsible for deliberate destruction of countless native ecosystems and Indigenous lives and cultures (Barnard, 2020; Paddle, 2000; Posthumus, 2016). Therefore, it is imperative that in telling the ecological and conservation history of native species, zoos explain their relationship to Indigenous cultures, the role that White Settler colonialism played in the destruction of native animals and Indigenous societies, and how contemporary Indigenous communities are supporting habitat and ecological restoration efforts. In the process of discussing the ecological impact of White Settler colonialism and White supremacy, it is also important that zoos as an institution reflect upon their own shameful past. As recently as 1958, zoos in North America and Europe hosted human zoo exhibits, where colonized and indigenous people were displayed alongside animal exhibits to serve as propaganda to justify colonialism through “scientific racism” (Conklin & Fletcher, 1999; Ito, 2014; Lewis et al., 2013; Putnam, 2012). Thus, efforts to incorporate IK into their conservation narratives should also acknowledge direct harms to indigenous peoples and communities caused by zoos.

In this paper, we examine how two zoos (Meadowdale and Belmont, both pseudonyms) from two post-colonial White Settler nations (the US and Canada respectively) portray Indigenous peoples and IK in their informational signage on native animals (animals native to these nations). We are interested in describing the different approaches these two zoos use to acknowledge the presence of indigenous peoples and to incorporate IK in their signage. We will also reflect on how these two zoos represent the history and legacy of colonialism in their exhibits on native animals and the implications for the field of informal science education.

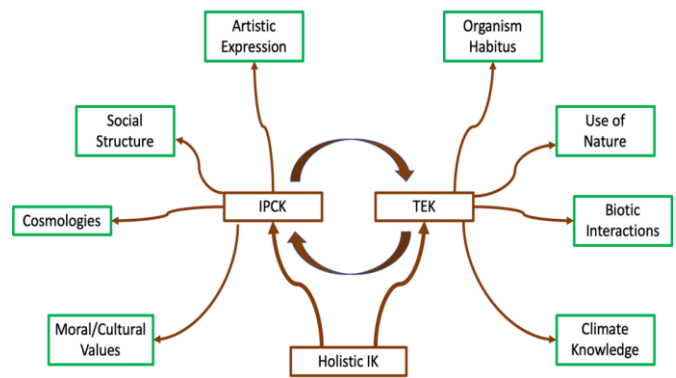
## THEORETICAL FRAMEWORK

While IK can be defined as any knowledge that has been produced by Indigenous communities, there are unique characteristics of IKS that helps distinguish IK from Western ways of knowing and WMS in particular. IKS tend to avoid the generalizability and essentialization that is ubiquitous in WMS in favor of more localized and holistic understandings (Aikenhead & Ogawa, 2007; Kim et al., 2017; van Eijck & Roth, 2007; Zidney et al., 2020). This highly place-based approach to knowledge gives IKS a depth and nuance often lacking in the more universalist WMS tradition (Brayboy & Castagano, 2008; Datta, 2018; Kim et al., 2017; van Eijck & Roth, 2007; Sutherland & Swayze, 2012). Additionally, long term observation and characterization of local environments is a critical part of many IKS and has the potential to reveal long term patterns within the natural world, such as the decades long alternations between wet and dry periods found in the American Southwest (Aikenhead & Ogawa, 2007; Barnhardt & Kawagley, 2005; Redsteer et al., 2013). Finally, IKS are not as constrained by the dualistic assumptions of Western ways of knowing. One of the distinguishing characteristics of Western knowledge systems is the belief in a strong separation between spiritual/cultural and material/natural spheres, often referred to as the nature/culture divide (Bang et al., 2012; Haila, 2000; Helmreich, 2009; Sowards, 2006). This dualism has facilitated

exploitative attitudes towards the natural world, leading to environmental degradation (Helmreich, 2009; Sowards, 2006; Uggla, 2010). Contrastingly, IKS often find inherent spiritual value in natural landscapes and are less likely to prioritize human economic development over long-term sustainability (Uggla, 2010).

Although IK, like WMS, exists within a broader context of spiritual and cultural beliefs, when IK is shared outside of its Indigenous communities by non-indigenous groups, many of the more holistic aspects of IK, such as Indigenous cosmologies and worldviews, are often removed or diluted in order to appeal to a settler colonialist audience (Kim et al., 2017; Zidny et al., 2020). Therefore, we have constructed the “westernized indigenous ecological knowledge” (WIEK) framework to describe the different aspects of IK of ecosystems that can be conveyed to a predominately settler colonialist audience in an informal science learning environment, such as a zoo (Figure 1). It is important to note that while this framework is useful for categorizing the aspects of IK that Westerners are attempting to communicate through zoo signage and other forms of communication, this framework is not aiming to reflect how IKS exist within their indigenous communities. At the base of this model is “holistic IK”, which describes the interweaving of environmental/ecological knowledge with indigenous cosmologies and worldviews (Barnhardt & Kawagley, 2005; Battiste, 2009; Berkes & Berkes, 2009; Kim et al., 2017). This approximates how IK has traditionally existed with indigenous communities and therefore is what informal learning institutions should seek to convey to their audience.

Out of this holistic base, there are two main ways that Westerners can compartmentalize IK: indigenous philosophical and cultural knowledge (IPCK) and traditional ecological knowledge (TEK). These two branches correspond roughly to the nature/culture dualism that exists in WMS and Western society at large (Descola, 1996; Haila, 2000; Uggla, 2010). It is important to note that despite depicting these as separate branches, IPCK and TEK are naturally heavily intertwined and support each other; this interconnectedness is shown through the circular arrows in our framework (Figure 1). IPCK corresponds to broader anthropological descriptions of “culture” and describes the various moral/cultural values, philosophies, cosmologies, and worldviews that indigenous communities use to make sense of the world and humanity’s relationship to nature as well as the expression of these ways of knowing through art (Abdul Ghani Azmi, 2017; Faulkner et al., 2006; Magallanes, 2015; Oppenheimer, 2009; Roy, 2015). IPCK can be communicated to outsiders through sharing morality tales (stories meant to highlight certain moral truths), cosmologies (beliefs about how the world came to be and humanity’s place in the cosmos), the social structures of indigenous societies, and indigenous art. While IPCK can be presented on its own, it often intersects and informs indigenous understandings of ecological knowledge (Kim et al., 2017; Magallanes, 2015). For example, a morality tale about a young woman marrying a rich crow to find out that her new husband is a detritivore communicates both ecological knowledge and cultural beliefs.



**Figure 1.** Westernized indigenous ecological knowledge framework (Source: Authors’ own elaboration)

In contrast to the more cultural and spiritual elements present in IPCK, our conceptualization of TEK emphasizes aspects of IK of natural ecosystems that more closely correspond with Western understandings of ecology. TEK describes the collective knowledge an Indigenous community has gathered about their local environment (Lowan, 2012; Mack et al., 2012; Ogawa, 1995; Snively & Corsiglia, 2001). When IK of natural ecosystems is adapted for WMS, it is often stripped of its cultural context and IPCK (Kim et al., 2017; Zidny et al., 2020); therefore, some scholars suggest that the term TEK be used to describe this intersection between IKS and WMS (Kim et al., 2017; Kim & Dionne, 2014; Zidny et al., 2020). For our purposes, we examine four main aspects of TEK: organism habitus, indigenous use of nature, knowledge of biotic interactions, and climate knowledge. “Habitus” describes both the physiological and behavioral traits of a species. In our framework “organism habitus” refers to IK of organism physiology, life cycles, behavior and how these organisms interact with abiotic forces in their environment. “Indigenous use of nature” describes how indigenous communities make use of local plants, animals, and other aspects of nature (such as minerals). A subcategory of this is indigenous medical knowledge. “Biotic interactions” describe relationships that exist between different organisms in an ecosystem. Finally, “climate knowledge” refers to indigenous understandings of weather patterns, seasonal changes, and broader climate trends.

## Background

### *Zoos as centers for informal science learning*

With over 150 million annual visitors, zoos have the potential to reach more individuals than almost any other informal learning site (Milstein, 2009; Visitor Demographics, 2019). Their vast collections of diverse flora and fauna create an environment, where both child and adult learners are primed to ask questions about key science topics including natural selection/evolution, animal physiology, food webs/ecosystems, and environmental sustainability/climate science (Fogelberg, 2014; Macdonald & Whiten, 2011; Kelly et al., 2014; Luebke et al., 2012; Wagoner & Jensen, 2010). While zoo staff have opportunities to directly communicate science content to guests (Patrick, 2014) through either one-on-one conversations or through interactive animal encounters these interactions are not necessarily available to every visitor.

Animal encounters typically have capacity limitations, are often only offered at select times of the day, and maybe completely unavailable during times when zoo attendance is anticipated to be lower than expected (i.e., weekdays and “off seasons”). Likewise, zoo staffing is also contingent on seasonal zoo attendance patterns. This means that zoos often make use of other forms of information delivery to communicate to their guests such as informational signage.

Zoos often use informational signs to communicate key ideas to visitors (Fogelberg, 2014; Fourage et al., 2022; Marshall, 2016; Yocco et al., 2010). While some of these signs are purely utilitarian (such as signs imploring guests not to feed the animals on display), they often display key information meant to educate zoo visitors (Fogelberg, 2014; Fourage et al., 2022; Marshall, 2016). Many zoo signs provide basic information about the animal on display such as taxonomy, diet, behavior, life cycle, and habitat location. Given the conservation goals of contemporary zoos, these signs often provide information about a species’ conservation status and actions that can be taken to promote the welfare of particularly vulnerable species (Clayton et al., 2009; Dove, 2016; Fogelberg, 2014; Fourage et al., 2022; Marshall, 2016). Zoo signs can also provide opportunities for zoos to acknowledge indigenous cultures. For example, if a zoo includes a thematic element from a particular indigenous culture (such as a Pueblo style adobe building), they can include a placard explaining IK behind such a structure. Zoos can also include TEK about a particular species as well as IPCK associated with a particular species. Despite the opportunities of using zoo signs to create a narrative for zoo visitors, studies suggest that depressingly few visitors read zoo signs (Clayton et al., 2009; Marshall, 2016; Ogle, 2016; Yocco et al., 2010). This often forces zoos to consider ways they can modify their signs to maximize visitor engagement. Such changes include adding interesting graphics and font choices to attract visitor attention, minimizing word counts and simplifying language to reach and retain more readers, and optimizing sign placement to complement exhibit theming and increase the odds of people noticing key signs (Dove, 2016; Marshall, 2016; Ogle, 2016).

### Research Questions

Given their history and in light of their potential as powerful resources for teaching and learning, we were interested in investigating how two contemporary zoos in North America are approaching Indigenous cultures and IK through their signage. In this study we sought to focus on zoos that have taken efforts towards including IK in their exhibits on native animals in an effort to answer the following research questions:

1. What aspects of IK are being represented through informational signage?
2. How is the impact of colonialism in North America on animals and Indigenous people conveyed through informational signage?

To answer these questions, we conducted a comprehensive analysis of the North American sections of two zoos (Meadowdale in the Midwestern US and Belmont in Eastern Canada) based on photographic evidence taken from in-person visits to these zoos.

## METHODS

### Positionality Statement

As researchers of White German and Swiss heritage (Jonathan Bowers) and Hungarian heritage (Gail Richmond) living on land that was stolen from Indigenous peoples, we recognize the importance of acknowledging the Indigenous peoples of this land and our ancestors’ role in perpetuating White Settler colonialism. Jonathan Bowers grew up on land that was historically inhabited by the Myaamiaki (Miami), the Shawnee, the Anishinaabe, and other Indigenous peoples prior to the establishment of European settlement in that region, while Author 2 grew up on land largely inhabited by the Nanticoke Lenni-Lenape, Powhatan Renape, and Ramapough Lenape Indian Nations. We acknowledge that White European settlers cut down forests, planted corn, and built settlements on land that was unlawfully stolen. Although not all of our White ancestors participated in this initial destruction, we recognize how we as White Americans have unjustly benefited from these past actions and ongoing discrimination against Indigenous peoples. While we cannot undo these past wrongs, through amplifying Indigenous voices and Indigenous perspectives, we strive to honor the victims of White Settler colonialism and to promote justice for all Indigenous people.

Jonathan Bowers personally became interested in indigenous issues in education (particularly in reference to zoos) following his experiences in a graduate level course taught by Gail Richmond. In addition to reading key works by indigenous authors (particularly *Braiding Sweetgrass* by Robin Wall Kimmerer, 2013), both authors were emotionally impacted by the tragic discovery of the graves of Indigenous children in Kamloops, British Columbia. Jonathan Bowers also became aware of atrocities committed against Indigenous people by zoos, many of which kept Indigenous people in cages alongside animals. As a result, these two authors decided to investigate how contemporary zoos were addressing IK, through their exhibits on native animals.

### Zoo Locations

In order to protect the identities and professional reputations of our zoo partners, we decided to keep these two zoo locations anonymous. We also recognize the importance of place in understanding IK. Therefore, to maintain the anonymity of the zoos and to provide the necessary context to understand each zoo, we gave each zoo a pseudonym along with a summary table of the indigenous peoples who historically inhabited that region (**Table 1**). The two zoos in question were selected due to a combination of selective criteria and geographic convenience. Both the Meadowdale and Belmont zoos are in large urban regions, contain large sections dedicated to North American wildlife, have indigenous cultures represented through exhibit theming and informational signage, and are geographically accessible to the authors. The Meadowdale Zoo has three sections containing predominately North American animals: a naturalistic Great Lakes Wetlands section, a section for Western North American Mammals, and an Arctic Circle section. The Belmont Zoo has a section dedicated to the Canadian Woodlands and a section dedicated to the Canadian Tundra.

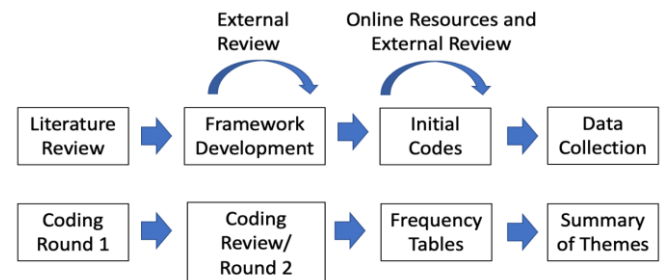
**Table 1.** Summary of zoo study sites

Zoo pseudonym	Zoo location	Indigenous peoples	Percent indigenous of region
Meadowdale Zoo (Wetlands, Western NA Mammals, Arctic)	Great Lakes Region (US)	Anishinaabe, Wyandot (Huron), Haudenosaunee (Iroquois), Saux, Fox, Mascouten, Shawnee, and Myaamiaki (Miami) peoples (Cleland, 1992; Edmunds, 2008; Nichols, 2018)	<0.5% (US Census Bureau, 2010)
Belmont Zoo (Woodlands, Tundra)	Eastern Canada	Anishinaabe, Wendat (Huron), Haudenosaunee (Iroquois), Mississaugas, Mi'kmaq, Montagnais, and Abenaki (Ray & Conaty, 1998; Rogers & Smith, 1994).	~ 3% (Statistics Canada, 2016)

## Methodology

To analyze the written content from informational signs, we employed the thematic analysis method of qualitative data analysis (Kiger & Varpio, 2020). Thematic analysis is a broad methodology that can be applied to many different types of data and used in conjunction with almost any theoretical framework (Braun & Clarke, 2006; Kiger & Varpio, 2020; Ocampo-Agudelo & Maya, 2017). The patterns that emerge from this kind of analysis are known as “themes”, which scaffold both the data analysis process and how the findings are ultimately presented (Braun & Clarke, 2006; Kiger & Varpio, 2020; Ocampo-Agudelo & Maya, 2017). In general, thematic analysis methods rely on a mixture of deductive reasoning (applying a preexisting framework to analyze a set of data) and inductive reasoning (observing patterns within the data to generate a novel framework), which happen as one constructs and refines their conceptualizations of the key “themes” that emerge from the analytic process (Braun & Clarke, 2012; Kiger & Varpio, 2020; Varpio et al., 2019). In the deductive stages of thematic analysis, researchers often use preexisting frameworks to create lists of possible “thematic codes” (qualitative categories that can be used to identify patterns). Meanwhile, by applying these thematic codes, researchers will use inductive reasoning to identify themes that are emerging from their data. Through these cycles of deductive code generation and inductive thematic analysis, researchers can develop robust findings that resonate with other literature (Kiger & Varpio, 2020; Ocampo-Agudelo & Maya, 2017).

For this study, we used an iterative process of thematic analysis to address our two main questions (This process is depicted in **Figure 2**). We began by reviewing the existing literature on IK (and its portrayal by Western institutions) and reflecting on the historic and contemporary relationships between Indigenous peoples and White Settlers in North America. This led us towards creating WIEK framework (**Figure 1**), which guides our subsequent thematic coding for addressing how zoos are representing IK (question 1) through their informational signage. This framework was reviewed by several colleagues who provided meaningful feedback that helped us revise this framework and construct initial thematic codes. Once the initial thematic codes were created, reviewed, and revised, we scheduled visits to the zoo sites. After our zoo visits, we applied our existing thematic codes to our photographic data. We then had an in-depth discussion about our coding results and made modifications to our thematic codes based on this conversation. We subsequently undertook a second round of thematic coding based on our revisions, organizing these thematic codes into a set of frequency tables for each zoo section. These frequency tables helped us identify which aspects of IK were most prominent at each zoo and



**Figure 2.** Thematic coding flowchart (Source: Authors' own elaboration)

helped us develop our thematic summaries for each zoo section.

## Data Collection & Storage

For both the Belmont and Meadowdale zoos, we conducted onsite visits during normal zoo operating hours. Using a cell phone camera, we systematically photographed every informational sign present in the two Belmont Zoo and the three Meadowdale Zoo sections dedicated to North American wildlife. To ensure a thorough documentation, we went through each zoo section twice. Once we took these initial photos, we uploaded them to a secure server accessible only to the two authors. We subsequently transcribed every informational sign.

## Thematic Codes

Here we review our rationale behind our coding rubrics and explain how these rubrics were used to analyze our data and generate meaningful themes.

### Research question 1: Indigenous knowledge through informational signage

For this research question, we opted to use the categories of IK as described by our WIEK framework. These categories are primarily meant to help us illustrate how Westerners often separate aspects of IK into distinct categories when presenting this information to a predominantly non-indigenous audience. These categories are also useful for identifying aspects of IK that are present or are absent from these zoo sections. For IPCK, we have four categories that broadly reflect how aspects of indigenous philosophy and culture can be portrayed by zoos: “moral/cultural values”, “cosmologies”, “social structures and organization”, and “artistic expression”. For TEK, five categories are present: “climate knowledge”, “biotic interactions”, “use of nature”, “medical knowledge”, and “organism habitus”. Note that all examples of “medical knowledge” are also coded as “use of nature” as “medical knowledge” is a subset of this broader category (**Table 2**).

**Table 2.** Thematic codes for assessing IK on informational signs using WIEK framework

Name	Description	Examples
Moral/cultural values	Signs that reference indigenous moral or cultural values (beliefs governing ethical decision making) includes morality stories.	A sign depicting a story about how glooscap gave raccoons black circles around their eyes as punishment for stealing.
Cosmologies	Signs that reference indigenous beliefs about the creation of the world or humanity's place in the cosmos.	A sign describing the Turtle Island Narrative about how the world was created on the back of a turtle.
Social structures & organization	Signs that explain how indigenous society is (or has been) organized (includes clan systems, gender roles, rites of passage, etc.).	A sign discussing the clan system of the Anishinaabe people.
Artistic expression	Signs that describe an art installation created by indigenous artists or reference the use of art by indigenous cultures.	A sign describing a sculpture of a walrus made by an indigenous artist.
Climate knowledge	Signs that reference Indigenous understanding of weather patterns, seasonal changes, and long term climate patterns.	A sign discussing how the Cree people migrated to different areas based on seasonal climate differences to take advantage of seasonal resources (ala geese).
Biotic interactions	Signs that reference indigenous understandings of the interactions between two or more species in nature. (e.g., predator/prey relationships, symbiotic relationships, etc.)	A sign that describes an indigenous tapestry showing a polar bear eating a seal.
Use of nature	Signs that describe how indigenous people used nature to meet their needs. Can include medical knowledge, food sources, shelter, clothing, and tool use.	A sign that explains how the Haudenosaunee used dried wild grapes as food sources on long hunting trips.
Medical knowledge	Signs that describe how indigenous communities used plants or other resources as medicine.	A sign describing how an indigenous community used Colt's Foot as a cough dispeller
Organism habitus	Signs that reference indigenous understandings of organism behavior, morphology, physiology, and/or lifecycle. Can include descriptions of the environments where indigenous people knew to look for certain plants.	A sign discussing a morality tale that references indigenous understandings of how Raccoons often "steal" food (as raccoons are scavengers and often take food from human settlements).

Each sign from each zoo section was classified according to which forms of IK were present on each sign. Because multiple forms of IK might be present on an individual sign, it was necessary to document the synergy between these forms of IK, especially if they combine elements of IPCK and TEK. Once each sign was categorized for a section of the zoo, a frequency table, summarizing the different types of IK being represented in said section was presented in the results section. These composite tables were then used to scaffold a discussion of the different themes that emerge from this analysis.

### **Research question 2: Discussions of the impact of settler colonialism on indigenous cultures and North American ecosystems**

Given the catastrophic impacts settler colonialism has had upon both the natural environment and indigenous communities, we found it necessary to explore how the five sections of these two North American zoos are addressing this history through informational signage. Unlike the previous category, this set of codes is more inductive in nature and based more on iteratively refining these codes based on our observations. To limit confounding discourses and minimize the risk of confirmation bias, we decided to narrow our scope of Settler Colonialism to efforts taken to establish White Settler dominance over North America prior to 1924 (the establishment of the Indian Citizenship Act in the US, which represents a shift in settler colonial policy from westward expansionism towards aggressive assimilation). While we recognize that many of the present ecological challenges resulting from industrialization have their roots in Settler Colonialism (Whyte, 2016a, 2016b) we felt that including discussions of climate change in this analysis would be unproductive as neither of these zoos were explicitly making a connection between industrial development and settler colonialism.

Based on our observations of what was (and what was not) present on informational signs in these five sections, we came up with a three-tier system for determining how zoo signs were approaching the historical impacts of settler colonialism. At the lowest level is "euphemistic discussions of the impact of settler colonialism on wildlife". This category describes signs that discuss actions taken by White settlers that have caused ecological harm but do not directly attribute these actions to White settlers or European colonizers. A sign that argues that "Overhunting and lax gun laws led the Bison towards extinction", would be an example of a euphemistic discussion as it avoids giving direct blame to White settlers. Conversely a sign that states that "European demand for fur products from North America led to a massive decrease in Beaver populations in the Great Lakes Region" would be an example of "direct discussions of the impact of settler colonialism on wildlife" as it directly mentions how White settlers/European colonizers impacted North American wildlife. The final tier of this coding scheme, "direct discussions of the impact of settler colonialism on indigenous peoples", is reserved for signs that directly mention how settler colonialism has negatively impacted indigenous communities.

## **RESULTS**

### **Research Question 1: What Aspects of IK Are Being Represented Through Informational Signage in These Two Zoos?**

#### ***Meadowdale wetlands and North American mammals***

Neither the "wetlands" section or the "North American mammals" sections of the Meadowdale Zoo contained a significant number of signs addressing IK or acknowledging the historic presence of indigenous people in North America.

Sign Summary	Sign Focus	Morality/Cultural Values	Cosmology	Social Organization	Artistic Representations	Organism Habitus	Biotic Interactions	Use of Nature	Medical Knowledge	Climate Knowledge
Exploiters	Humans	0	0	0	0	0	0	1	0	0
Treacherous waters	Humans	0	0	0	0	0	0	1	0	0
Ptarmigan	Animal	0	0	1	1	0	0	1	0	0
Dancer	Humans	0	0	1	1	0	0	0	0	0
Caribou	Animal	0	0	0	1	1	0	1	0	0
Caribou 2	Animal	0	0	1	1	0	0	0	0	0
Mother and Child	Humans	0	0	1	1	0	0	0	0	0
Animals of N	Cosmology	1	0	0	1	0	0	0	0	0
Arctic Hare	Animal	0	0	0	1	1	0	1	0	0
Ravens Wife	Cosmology	0	1	0	1	0	0	0	0	0
Walrus	Animal	0	1	0	1	1	0	1	0	0
Bear and Kill	Animal	0	0	0	1	1	1	0	0	0
Musk Ox	Animal	0	0	0	1	1	0	1	0	0
Untitled	Animal	0	0	0	1	1	0	0	0	0
Bear Statue	Animal	0	0	0	1	1	0	0	0	0
Sedna	Cosmology	0	1	0	1	0	0	0	0	0
Falcon	Animal	0	0	0	1	1	0	0	0	0
Inuksuit	Cosmology	0	1	0	1	0	0	1	0	0
Shelters	Humans	0	0	1	0	0	0	1	0	1
The People	Humans	0	0	1	0	0	0	1	0	0
Average		0.05	0.2	0.3	0.8	0.4	0.05	0.5	0	0.05

Figure 3. Meadowdale arctic signs according to WIEK framework (Source: Authors’ own elaboration)

Out of 52 informational signs (21 in the wetlands section and 31 in the mammals section), only one sign directly addresses IK, by comparing how different cultures have portrayed wolves in their cultural narratives. This sign states that, “[In] native American culture, wolves are honored for their skillful and resourceful hunting ability as well as strong family loyalty. Tribes looked to the wolf for its power and bravery, endurance and discipline.” This statement on native American culture, is meant to contrast with Western viewpoints on wolves, with references to the trope of the “big bad wolf” in Western folklore also appearing on this sign. Overall, this sign demonstrates indigenous moral and cultural values, by pointing out the virtues of “bravery” and “discipline”, while also showing indigenous perspectives on the habitus of wolves, being that they are “skillful hunters” and have “strong family loyalty” (live in packs). Yet as this sign is the only one in these two sections to reference IK, Indigenous representation is largely absent from this area of the Meadowdale Zoo.

**Meadowdale arctic**

In contrast to the Meadowdale Zoo’s wetlands and North American mammals sections, the Meadowdale Zoo’s arctic section has many more examples of IK and indigenous cultural representation. Out of 45 signs and placards, 20 include examples of IK (Figure 3). By far the most common way IK is included in this section is through displays of indigenous art. The Nunavut gallery contains 15 pieces of Inuit art produced by contemporary artists, with informational placards describing each artwork and providing additional expressions of IPCK and TEK. Several of these artworks display Sedna, an important figure in inuit cosmology with a deep connection to marine life. In addition to representing Inuit cosmology, these placards frequently mention Inuit TEK, including their descriptions of animal behavior and other aspects of organism habitus and how Inuit people have made use of key species as sources of food and furs (use of animals). As such, we can say that there is a fair amount of synergy between displays of IPCK and TEK in the Nunavut gallery.

Outside of the Nunavut gallery, there are a few informational signs that contain representations of IK. For example, there are two signs that recognize the importance of Inuit TEK in helping their communities survive in the harsh Arctic environment and note how this knowledge was in turn

useful to European explorers. Other signs describe key aspects of Inuit material culture and spiritual practice, such as the use of Inuksuit (stone structures that act both as geographical markers for traversing the Arctic and have spiritual significance in Inuit cosmology). Finally, a key sign provides insights into contemporary Inuit society and their efforts to maintain cultural sovereignty within North America. Overall, the meadowlands arctic section presents a strong representation of the IPCK aspects of artistic representation and social organization alongside the TEK aspects of organism habitus and use of nature. This section also tends to position the Inuit as a living culture, which is important for dispelling the false narrative of the “vanishing native”. Despite these successes, the meadowlands arctic section largely ignores Indigenous morality and culture values as well as the TPK aspects of biotic interactions, medical knowledge, and climate knowledge, as measured by our coding scheme.

**Belmont woodlands**

With 23 out of its 47 informational signs and placards referencing IK, the Woodlands section of the Belmont Zoo has the highest proportion of signs incorporating IK (Figure 4). This is primarily due to its indigenous knowledge trail (IKT). Located adjacent to a small pond in the back of the Woodlands section, IKT is composed of 20 signs, dedicated to sharing IK of Indigenous communities from Canada’s Eastern Woodlands. Most of the signs on this trail emphasize aspects of TEK, particularly use of nature and medical knowledge of plants. For example, the sign for wild grapes states, “Traditionally, Anishinaabeg use the sap from grapevines as shampoo. On long hunting trips, the Haudenosaunee would pack up dried grapes and cakes made of mashed fruit.” This is a strong example of the “use of nature” aspect of TEK. Medical knowledge of plants is also well represented in this section, such as how indigenous communities would use Colt’s Foot as a cough dispeller.

Another common form of IK in the Woodlands section is the retelling of indigenous “morality tales”, a type of story that often uses fantastical elements and/or animal characters to address a moral/cultural value. One sign tells, “A Micmac story claims that the Raccoon was caught stealing by the legendary Glooscap. As punishment, Glooscap places black circles around the Raccoon’s eyes to remind others of the mistake he made.” This morality tale both addresses the cultural value

Sign Summary	Sign Focus	Morality/Cultural Values	Cosmology	Social Organization	Artistic Representations	Organism Habitus	Biotic Interactions	Use of Nature	Medical Knowledge	Climate Knowledge
Raccoon Thief	Animal	1	0	0	0	1	0	0	0	0
Introduction Sign	Humans	1	0	0	0	0	0	1	0	0
Bear Clan Sign	Humans	0	0	1	0	0	0	1	1	0
Black Willow	Plant	0	0	0	0	1	0	0	0	0
Eastern White Cedar	Plant	0	0	0	0	0	0	1	0	0
Colts Foot	Plant	0	0	0	0	0	0	1	1	0
Grizzly Bear	Animal	1	1	0	0	1	0	0	0	0
Fish Clan	Humans	0	0	1	0	0	0	0	0	0
Dogwood	Plant	0	0	0	0	0	0	1	1	0
Woodpecker	Animal	0	1	0	0	1	0	0	0	0
Wild Grape	Plant	0	0	0	0	0	0	1	0	0
Beaver Clan	Humans	0	0	1	0	0	0	0	0	0
White Ash	Plant	0	0	0	0	0	0	1	1	0
Blue Jay	Animal	1	0	0	0	1	0	0	0	0
Cattail	Plant	0	0	0	0	1	0	1	0	0
Storytelling	Humans	1	0	1	1	0	0	1	1	0
Clan System	Humans	0	0	1	0	0	0	0	0	0
Poison Ivy	Plant	0	0	0	0	1	0	1	1	0
Clan System 2	Humans	0	1	1	0	0	0	0	0	0
Salmon	Animal	0	1	0	0	1	0	1	0	0
Sunchasers	Humans	0	0	0	0	1	0	1	0	0
Trembling Aspen	Plant	0	0	0	0	0	0	1	0	0
American Robin	Animal	1	1	0	0	1	0	0	0	0
Average		0.26	0.22	0.26	0.04	0.43	0.00	0.57	0.26	0.00

Figure 4. Belmont woodlands signs according to WIEK framework (Source: Authors' own elaboration)

Sign Summary	Sign Focus	Morality/Cultural Values	Cosmology	Social Organization	Artistic Representations	Organism Habitus	Biotic Interactions	Use of Nature	Medical Knowledge	Climate Knowledge
Turtle Island	Cosmology	0	1	1	1	0	0	0	0	0
Turtle Island 2	Cosmology	1	1	0	1	0	0	0	0	0
Art	Humans	0	1	0	1	0	0	0	0	0
Canoes	Humans	0	0	0	0	0	0	1	0	0
Whales	Animal	0	0	0	0	0	0	1	0	0
Teepee	Humans	0	0	0	0	0	0	1	0	0
Goose Camp	Humans	1	0	1	1	1	0	1	0	1
Polar Bear	Animal	1	1	0	0	0	1	1	0	0
Upset Stomach	Humans	0	0	0	0	0	0	1	1	0
Mosquito Part 1	Animal	1	0	0	0	1	1	1	0	0
Mosquito Part 2	Animal	1	0	0	0	0	0	0	0	0
Mosquito Part 3	Animal	1	0	0	0	0	0	0	0	0
Mosquito Part 4	Animal	1	1	0	0	0	0	1	0	0
Labrador Tea	Plant	0	0	0	0	0	0	1	1	0
Tamarack	Plant	0	0	0	0	0	0	1	1	0
Burnt Wood	Plant	0	0	0	0	0	0	1	1	0
Fireweed Roots	Plant	0	0	0	0	0	0	1	1	0
Willow bark	Plant	0	0	0	0	0	0	1	1	0
Cattails	Plant	0	0	0	0	0	0	1	1	0
Reindeer Moss	Plant	0	0	0	0	0	1	1	1	0
Turtle Island 3	Cosmology	0	1	0	1	0	0	1	1	0
Average		0.33	0.29	0.10	0.24	0.10	0.14	0.76	0.43	0.05

Figure 5. Belmont tundra signs according to WIEK framework (Source: Authors' own elaboration)

that stealing is wrong and also provides an example of IK of animal habitus by portraying aspects of raccoon behavior (raccoons often function as scavengers and “steal” food from humans) and racoon physiology (raccoons have black circles under their eyes). In addition to these morality tales, IKT does discuss how the Anishinaabe have historically adopted a clan system with unique social roles for each clan. This is an example of “social organization” aspect of IPCK as it lays out how Anishinaabe society functioned. While many forms of IK were present here, artistic representations, biotic interactions, and climate knowledge were almost completely absent.

**Belmont tundra**

Although the Belmont Zoo’s tundra section is in the same zoo as its Woodland section, the proportion of signs containing IK in this section (21 out of 73 signs) is far lower (Figure 5).

However, it still has several strong examples of how IK can be incorporated into zoo signage. In a similar fashion to the arctic section at the Meadowdale Zoo, Belmont’s Tundra section has an associated art instillation, this time dedicated to Indigenous groups associated with the Great Lakes region. It prominently features the “Turtle Island” creation story common to the Anishinaabe and Haudenosaunee peoples. Likewise, in parallel to IKT of Belmont’s Woodlands section, the Tundra section features a small trail of placards dedicated to IK of medical uses of plants. For example, one placard says, “To expel intestinal worms, Cree used a lichen called ‘reindeer moss’.” A nearby trail of signs features a morality tale called

“The Legend of the Queen Mosquito”. In this narrative a young hunter was attacked by a swarm of mosquitoes while looking for spruce roots. The Queen mosquito took pity on him and cured him of his wounds and became his protector. This morality tale does emphasize the importance of mercy and cooperation, while also providing some insights into indigenous “use of nature” and the habitus of mosquitos (how they tend to attack humans in certain habitats).

In addition to these larger areas of the Tundra section dedicated to IK, there were a few additional signs containing IK scattered throughout this section of the Belmont Zoo. One of these signs discussed the rites of passage associated with “Goose Camp” (seasonal hunting of geese) in Cree culture. The “Goose Camp” sign reads, “In Spring and Fall, traditional Cree communities in Northern Ontario move to their hunting camps for several weeks at a time to hunt Canada and snow geese. Families work together to hunt and preserve the food for the next season. They set up traditional teepees as well as modern “trapper” tents as shelters in annual camp locations. Cree boys are taught at a young age – as early as three years old – to imitate goose calls. By the age of ten, they can be excellent callers. When the boys kill their first goose, they are honored by their family and community. This first goose head will be skinned, cleaned, stuffed, decorated with beads, and hung in their parents’ home. Everything in the Goose Camp has a purpose and a value. Knowledge about how to hunt, prepare food, and build tools and shelters has been passed onto the Cree today from their ancestors. These ancestors have also passed on the wisdom of treating animals and the land



**Table 3.** Discussions of settler colonialism on zoo signs

Zoo name	Zoo section	Level 1: Euphemistic discussions wildlife	Level 2: Direct discussions wildlife	Level 3: Direct discussions indigenous people
Meadowdale	Wetlands	2	1	0
Meadowdale	Mammals	5	1	0
Meadowdale	Arctic	2	1	0
Belmont	Woodlands	2	0	0
Belmont	Tundra	2	0	0

with respect. They understand that the health of all living things in the tundra depend on it.”

This sign successfully blends aspects of IPCK and TEK into a more holistic representation of IK. IK of geese behavior and migration patterns is supported by depictions of Cree social life through the rites of passage associated with “Goose Camp”. These discussion of Cree geese hunting practices is then related back to a discussion of Cree moral values of respecting wildlife and a desire to live sustainably with the natural world. This sign portrays the “Goose Camp” as part of a living cultural tradition that is rooted in the practical needs of the Cree people and shows their deep knowledge of their environment (including knowledge of their local climate patterns). While this sign is a strong example of how the Belmont Zoo is incorporating IK into its informational signage, there was a general absence of IK of climate elsewhere in the Tundra section. Despite having 14 signs in this section dedicated to discussing climate change and its impact on Northern Canada, only the aforementioned “Goose Camp” sign incorporated IK of climate.

### Research Question 2: How Are These Two Zoos Discussing Impact of Colonialism in North America on Animals & Indigenous People Through Informational Signs?

Across all five zoo sections, there are examples of signs referencing the ecological impacts of colonialism (Table 3). However, most of these signs utilize euphemisms and coded language to lessen the impact of these discussions. For example, a sign on Wood Bison in the Woodlands section of the Belmont Zoo states, “... the wood bison was no match for disease, overhunting, and habitat loss. Historically numbering over 168,000 and ranging throughout the boreal forests of Canada’s Western provinces and territories, the wood bison population dwindled to only a few hundred individuals by the late 1800’s.” While this sign does discuss the dramatic population decline in wood bison brought about by European colonialism and even alludes to some of the mechanisms of population decline, it does not directly attribute the cause of this decline to White Settlers. In contrast, there are a few zoo signs from the Meadowdale Zoo that directly attribute the population decline of North American animals to White Settlers. In the Wetlands section of the Meadowland Zoo, a sign on the beaver exhibit states, “for almost 200 years, beavers were trapped, killed, and traded to Europeans who wanted to make fur coats and hats. The destruction of their population, combined with the industrial pollution that was dumped into rivers, kept beavers away for more than 150 years.” This sign openly states that European colonizers and their desire for beaver pelts, had a dramatic impact on beaver populations. While there are three signs in the Meadowdale Zoo that directly address the impact of settler colonialism on

North American wildlife, none of the signs present in this study explore how settler colonialism negatively impacted indigenous communities.

## DISCUSSION

### Reflections on How Meadowdale & Belmont Zoos Portray IK & Colonialism

Based on our analysis of zoo signs from the Meadowdale and Belmont zoos, there is evidence that zoos are already making efforts to depict several different aspects of IK through their informational signs. Both zoos included several signs sharing indigenous perspectives on organism habitus as well as information on how indigenous cultures made use of nature to ensure their survival. Both the Woodlands and Tundra sections of the Belmont Zoo emphasized indigenous medical knowledge and how various indigenous cultures used plants for medicinal purposes. While these efforts at sharing IK of the medicinal use of plants can help zoo visitors appreciate the value of IK, most of the signs containing IK on the medicinal use of plants did not include corresponding information about IPCK. This lack of inclusion of Indigenous philosophical perspectives towards plant use from these signs can imply that Indigenous cultures view plants in a similar manner to Western cultures, as being mere objects that can be used by humans as we see fit. These signs therefore represent a missed opportunity to explore indigenous principles of reciprocity whereby the use of plants by humans comes with a corresponding obligation for humans to give back to the Earth.

Although IPCK was underrepresented in signs discussing indigenous medicine, IPCK was still present in zoo signs at both the Meadowdale and Belmont zoos. Both the Meadowdale Zoo’s Arctic section and the Belmont Zoo’s Tundra section had areas dedicated to Indigenous art created by Indigenous artists. These art installations were opportunities for these zoos to showcase indigenous cosmologies as well as other aspects of IK. Additionally, the Woodlands section of the Meadowdale Zoo explored the social structures of Anishinaabe society through its signs on the Anishinaabe clan system. Such displays of IPCK can provide zoo audiences with a deeper appreciation for the philosophical and moral understandings of indigenous cultures. There is always a risk that displays of indigenous cultural knowledge (especially displays of indigenous cosmologies) can come across as patronizing and demeaning towards indigenous communities. However, it is important to note that many of the signs displaying IPCK at both zoos appear to have been co-constructed with people from indigenous communities (due to either being part of indigenous art installations or part of a designated IKT) and

therefore tend to portray indigenous philosophies and culture in a more positive light.

Given that IKS do not tend to separate IPCK and TEK from each other, IK is at its most authentic when IK of nature is presented through the philosophical and cosmological lenses provided by their respective cultures (Kim et al., 2017; Zidny et al., 2020). Because zoo signs are a Western approach to sharing knowledge often created by and largely created for a predominantly Western audience, such synergy and authenticity in portraying IK is often difficult. When sharing indigenous artwork or morality tales, these informational signs occasionally include examples of indigenous understandings of organism habitus, but often do so in simplistic ways. For example, in sharing a Micmac morality tale about raccoons, the informational sign tacitly acknowledges that the Micmac people understood that raccoons often “steal” food and that they have black circles under their eyes. While these are examples of the habitus of raccoons, they are surface-level observations and obscure the deeper knowledge that the Micmac people have about how raccoons behave and their interactions with other organisms. One of the stronger examples of how zoos can portray the synergy between IPCK and TEK comes from the “Goose Camp” sign in the Tundra section of the Belmont Zoo describing the Cree tradition of goose hunting. This sign combines IK of goose behavior (Goose Habitus) and techniques for hunting geese with cultural perspectives including information on indigenous social structures and moral values (the need to treat nature and the land with respect). By including aspects of IPCK and TEK, this sign reflects the more holistic nature of IK and is therefore a more authentic representation of Cree IK than portraying either aspect separately.

While both the Meadowdale and Belmont Zoos offer strong examples of the potential of zoos to incorporate IK into their informational signs, there are still aspects of IK and broader indigenous perspectives that are underrepresented at each. Although the Tundra section of the Belmont Zoo and the Arctic section of the Meadowdale Zoo emphasize climate science, they largely ignore IK of climate patterns and how indigenous communities are particularly vulnerable to climate change. Indeed, despite having 14 signs dedicated to discussing climate change in the Tundra section of the Belmont Zoo, only the “Goose Camp” sign references IK of climate, with its reference being confined to seasonal weather patterns governing geese migrations. Given that many Indigenous communities have strong oral traditions that record key aspects of their local climates (such as frequency of extreme weather events or changes in animal migration patterns), IK can be a strong source of evidence for the ongoing impacts of climate change (Ford et al., 2016; Nakashima & Krupnik, 2018; Petzold et al., 2020). Additionally, because many indigenous communities, such as the Inuit, still depend on hunting and other traditional food gathering techniques for at least some of their survival needs, they are uniquely vulnerable to the impacts of climate change (Bardsley & Wiseman, 2012; Maldonado et al., 2016; Wenzel, 2009). As such, including IK and indigenous perspectives into the climate change narrative at both zoos appears to be a missed opportunity.

Both of the zoos investigated in this study also avoid raising the issue of the impact of settler colonialism on indigenous communities. While there are a few examples of the Meadowdale Zoo directly acknowledging how White European Settlers negatively impacted key North American animals, none of the informational signs we observed at either zoo directly discussed how settler colonialism negatively impacted indigenous communities in the US and Canada. Although we recognize the challenges involved in discussing the history of settler colonialism in an appropriate and succinct manner through zoo signs and that such signs may only be read by a relatively small number of zoo visitors, zoos do have an obligation to try to discuss this impact through their informational signs. This is particularly true for zoos that already are including IK into their signage. By including IK and indigenous perspectives without acknowledging the historical and ongoing injustices and violence committed against indigenous communities, such zoos are ignoring a key aspect of the indigenous experience and are missing a critical opportunity to advocate for justice for indigenous communities. For zoos that have historic ties to the phenomenon of “human zoos”, wherein indigenous people were often enslaved and displayed in a demeaning manner, acknowledging this shameful past in addition to signs discussing how settler colonialism continues to negatively impact indigenous communities is a critical step towards honesty, increased representation and inclusivity.

### Future Directions

Across the field of science education there is a growing awareness of the value and importance of IK (Cajete, 2000; Kim et al., 2017; Ogawa, 1995; Munroe et al., 2013; Quigley, 2009; Snively & Corsiglia, 2001; Singleton et al., 2021). In informal science learning spaces, including IK offers a way to better represent indigenous cultures and make indigenous people feel welcomed in these spaces (Brayboy & Castagano, 2008; Kafai et al., 2014; Tzou et al., 2019). Such representation is important for helping indigenous youth develop a stronger science identity and increasing the likelihood of pursuing careers in science (Cajete, 2020; Kafai et al., 2014). Additionally, IK and Indigenous ways of knowing are being increasingly recognized as valuable perspectives towards understanding the natural world (Bang et al., 2012; Brayboy & Castagano, 2008; Cajete, 2000; Datta, 2018; Kim et al., 2017; Sutherland & Swayze, 2012; van Eijck & Roth, 2007). Many of the challenges facing our modern world, including climate change, involve complex systems of interacting elements, whose behavior cannot easily be described through linear reasoning (Forrester, 1994; Hofman-Bergholm, 2018; Ledley et al., 2017; Stave & Hopper, 2007). As such, the holistic perspectives of IKS offer alternative epistemologies that can be used to approach these problems (Aikenhead & Ogawa, 2007; Kim et al., 2017; van Eijck & Roth, 2007; Zidney et al., 2020). Likewise, the anthropocentric and dualistic nature of Western thought has been used for centuries to justify environmental exploitation, leading to our present environmental crisis (Bang et al., 2012; Haila, 2000; Helmreich, 2009; Sowards, 2006). Indigenous thought instead argues that humans have obligations to nature and therefore provides an alternative framework that could guide humanity

towards a more sustainable future (Bang et al., 2012; Kimmerer, 2013; Uggla, 2010).

We also argue that there is a need for informal science learning spaces, especially zoos, to use IK as an opportunity to open a broader conversation on the impact of colonialism on both the natural environment and on indigenous cultures. The North American landscape was irrevocably altered by European colonialism (Whitney, 1996). From the introduction of earthworms in Eastern Canada, to the vast deforestation of the Midwest, to the near extinction of American Bison, almost all aspects of North American ecology were permanently transformed by White Settlers (Bonan, 1999; Hubbard, 2014; Posthumus, 2016; Whitney, 1996; Wysote & Morton, 2019). Therefore, it is impossible to give an accurate account of North American ecological history without discussing the impacts of settler colonialism upon this continent. Likewise, the ongoing impact of colonialism upon indigenous communities should also be acknowledged by zoos and other informal learning spaces. Given the historical atrocities committed against indigenous people by zoos as an institution, we argue that zoos should address both their past misdeeds as well as broader patterns of injustice against indigenous communities. Such acknowledgements provide much needed context for zoo visitors and can spark broader discussions on contemporary challenges facing indigenous communities.

While both zoos studied made substantial efforts to incorporate IK and Indigenous perspectives into their informational signage, we acknowledge that many zoos (even those featuring large exhibits on native animals) ignore IK and the ongoing legacy of Indigenous cultures in North America. We also recognize that there are further opportunities for all zoos to expand their representations of IK and Indigenous cultures. Additionally, it is important to understand how zoos decide which aspects of IK to include in their informational signs. Future studies should prioritize interviewing zoo staff to understand decision-making process behind choosing how to represent IK and Indigenous perspectives through zoo signage.

We also advocate for involving (and properly compensating) indigenous leaders in any effort to incorporate IK and indigenous representations within informal science learning spaces to ensure that representation is handled in a respectful manner and is not patronizing to the communities and cultures we are striving to uplift. Likewise, we also would like to investigate additional ways that zoos can partner with indigenous communities to promote their broader aims of educating the public and promoting animal conservation. Finally, we recognize the potential zoos have for being places that can uplift both IK and indigenous communities. As one of the largest sets of informal science learning institutions in the world, zoos have the unique ability to reach large audiences who might not otherwise engage with informal learning spaces. Therefore, we see zoo signs as being an opportunity to not only share IK, but as places to advocate for indigenous communities and areas, where zoos can bring awareness to historic and ongoing injustices against indigenous peoples.

**Author contributions:** **JRB:** co-developed theoretical framework, collected all data from all zoo sites, conducted initial data analysis, & composed majority of manuscript & **GR:** served as a mentor & PI throughout this study, assisted in creating study's theoretical framework & served as a primary reviewer for analyzing thematic

codes, provided feedback on this manuscript, & co-authored key sections of this paper. All authors have agreed with the results and conclusions.

**Funding:** No funding source is reported for this study.

**Ethical statement:** That authors stated that given that data for this study were obtained from a publicly available source (zoo informational signs), which are accessible to general public on a daily basis, we believe that this study is exempt from needing formal approval of an ethics review board. To protect identity of these zoos, they deliberately chose to anonymize names and locations of them to the best of our ability. The authors further stated that, given that this study was part of a broader project that included interviews with zoo staff at these locations, they included IRB approval form from the ethics committee for the purpose of this review package. The IRB approval was conducted by the Office of Regulatory Affairs, Human Research Protection Program at Michigan State University under the approval number of STUDY00006175.

**Declaration of interest:** No conflict of interest is declared by authors.

**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.

## REFERENCES

- Abdul Ghani Azmi, I. M. (2017). Voices from the dead: The uneasy case of indigenous cultural expression. *International Journal of Law and Management*, 59(4), 522-533. <https://doi.org/10.1108/IJLMA-03-2016-0027>
- Adams, D. W. (1995). *Education for extinction: American Indians and the boarding school experience, 1875-1928*. University Press of Kansas.
- Adams, J. D., & McCullough, S. (2021). Inquiry and learning in informal settings. In R. G. Duncan, & C. Chinn (Eds.), *International handbook of inquiry and learning* (pp. 358-370). Routledge. <https://doi.org/10.4324/9781315685779-24>
- Aikenhead, G. S. (2001). Integrating Western and aboriginal sciences: Cross-cultural science teaching. *Research in Science Education*, 31(3), 337-355. <https://doi.org/10.1023/A:1013151709605>
- Aikenhead, G. S., & Elliott, D. (2010). An emerging decolonizing science education in Canada. *Canadian Journal of Science, Mathematics and Technology Education*, 10(4), 321-338. <https://doi.org/10.1080/14926156.2010.524967>
- Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education*, 2(3), 539-620. <https://doi.org/10.1007/s11422-007-9067-8>
- Ballantyne, R., & Packer, J. (2016). Visitors' perceptions of the conservation education role of zoos and aquariums: Implications for the provision of learning experiences. *Visitor Studies*, 19(2), 193-210. <https://doi.org/10.1080/10645578.2016.1220185>
- Bang, M., Medin, D. L., & Atran, S. (2007). Cultural mosaics and mental models of nature. *Proceedings of the National Academy of Sciences*, 104(35), 13868-13874. <https://doi.org/10.1073/pnas.0706627104>

- Bang, M., Warren, B., Rosebery, A. S., & Medin, D. (2012). Desettling expectations in science education. *Human Development, 55*(5-6), 302-318. <https://doi.org/10.1159/000345322>
- Bardon, J. (2022). Indigenous leaders, lawyers call for promised closure of Don Dale Youth Detention Center near Darwin. *ABC News*. <https://www.abc.net.au/news/2022-01-04/protesters-call-for-don-dale-youth-detention-centre-closure-nt/100736342>
- Bardsley, D. K., & Wiseman, N. D. (2012). Climate change vulnerability and social development for remote indigenous communities of South Australia. *Global Environmental Change, 22*(3), 713-723. <https://doi.org/10.1016/j.gloenvcha.2012.04.003>
- Barnard, J. L. (2020). The bison and the cow: Food, empire, extinction. *American Quarterly, 72*(2), 377-401. <https://doi.org/10.1353/aq.2020.0023>
- Barnhardt, R., & Kawagley, A. O. (2005). Indigenous knowledge systems and Alaska native ways of knowing. *Anthropology and Education Quarterly, 36*, 8-23. <https://doi.org/10.1525/aeq.2005.36.1.008>
- Barsh, R. L., & Marlor, C. (2003). Driving bison and blackfoot science. *Human Ecology, 31*(4), 571-593. <https://doi.org/10.1023/B:HUEC.0000005514.93842.91>
- Battiste, M. (2009). Naturalizing Indigenous knowledge in eurocentric education. *Canadian Journal of Native Education, 32*(1), 5-18.
- Berkes, F., & Berkes, M. K. (2009). Ecological complexity, fuzzy logic, and holism in indigenous knowledge. *Futures, 41*(1), 6-12. <https://doi.org/10.1016/j.futures.2008.07.003>
- Bonan, G. B. (1999). Frost followed the plow: Impacts of deforestation on the climate of the United States. *Ecological Applications, 9*(4), 1305-1315. [https://doi.org/10.1890/1051-0761\(1999\)009\[1305:FFTPIO\]2.0.CO;2](https://doi.org/10.1890/1051-0761(1999)009[1305:FFTPIO]2.0.CO;2)
- Bonnette, R. N., Crowley, K., & Schunn, C. D. (2019). Falling in love and staying in love with science: Ongoing informal science experiences support fascination for all children. *International Journal of Science Education, 41*(12), 1626-1643. <https://doi.org/10.1080/09500693.2019.1623431>
- Braun V., & Clarke V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Braun V., & Clarke V. (2012). Thematic analysis. In H. Cooper (Ed.), *APA handbook of research methods in psychology*. American Psychological Association. <https://doi.org/10.1037/13620-004>
- Brayboy, B. M. J., & Castagno, A. E. (2008). How might native science inform "informal science learning"? *Cultural Studies of Science Education, 3*(3), 731-750. <https://doi.org/10.1007/s11422-008-9125-x>
- Cajete, G. (2000). *Native science: Natural laws of interdependence*. Clear Light Publishers.
- Cajete, G. A. (2020). On science, culture, and curriculum: Enhancing native American participation in science-related fields. *Tribal College, 31*(3), 40-44.
- Cassidy, J. (2006). The stolen generations: Canada and Australia: The legacy of assimilation. *Deakin Law Review, 11*(1), 131-177. <https://doi.org/10.21153/dlr2006vol11no1art230>
- Clayton, S., Fraser, J., & Saunders, C. D. (2009). Zoo experiences: Conversations, connections, and concern for animals. *Zoo Biology, 28*(5), 377-397. <https://doi.org/10.1002/zoo.20186>
- Cleland, C. E. (1992). *Rites of conquest: The history and culture of Michigan's native Americans*. University of Michigan Press. <https://doi.org/10.3998/mpub.9272>
- Clifford-Clarke, M. M., Whitehouse-Tedd, K., & Ellis, C. F. (2022). Conservation education impacts of animal ambassadors in zoos. *Journal of Zoological and Botanical Gardens, 3*(1), 1-18. <https://doi.org/10.3390/jzbg3010001>
- Conklin, A. L., & Fletcher, I. C. (Eds.). (1999). *European imperialism, 1830-1930: Climax and contradiction*. Houghton Mifflin Co.
- Datta, R. K. (2018). Rethinking environmental science education from Indigenous knowledge perspectives: An experience with a Dene first nation community. *Environmental Education Research, 24*(1), 50-66. <https://doi.org/10.1080/13504622.2016.1219980>
- Dickson, C., & Watson, B. (2021). Remains of 215 children found buried at former B.C. residential school, first nation says. *CBC News*. <https://www.cbc.ca/news/canada/british-columbia/tk-eml%C3%B4ps-te-secw%C3%A9penc-215-children-former-kamloops-indian-residential-school-1.6043778>
- Dove, T. (2016). Investigating factors which affect visitor understanding of the information displayed on species signs: A multi-method evaluation approach. *IZE Journal, 52*, 39-42.
- Dunlop, L., Clarke, L., & McKelvey-Martin, V. (2019). Free-choice learning in school science: A model for collaboration between formal and informal science educators. *International Journal of Science Education, Part B, 9*(1), 13-28. <https://doi.org/10.1080/21548455.2018.1534023>
- Edmunds, R. D. (2008). *Enduring nations: Native Americans in the Midwest*. University of Illinois Press.
- Eichler, L. J. (2020). Ecocide is genocide: Decolonizing the definition of genocide. *Genocide Studies and Prevention: An International Journal, 14*(2), 9. <https://doi.org/10.5038/1911-9933.14.2.1720>
- Enslin, P., & Horsthemke, K. (2015). Rethinking the 'Western tradition'. *Educational Philosophy and Theory, 47*(11), 1166-1174. <https://doi.org/10.1080/00131857.2014.991501>
- Faulkner, S. L., Baldwin, J. R., Lindsley, S. L., & Hecht, M. L. (2006). Layers of meaning: An analysis of definitions of culture. In J. R. Baldwin, S. L. Faulkner, M. L. Hecht, & S. L. Lindsley (Eds.), *Redefining culture: Perspectives across the disciplines* (pp. 27-51). Routledge.
- Fogelberg, K. (2014). Unsilencing voices: A study of zoo signs and their language of authority. *Cultural Studies of Science Education, 9*(4), 787-799. <https://doi.org/10.1007/s11422-013-9566-8>

- Ford, J. D., Cameron, L., Rubis, J., Maillet, M., Nakashima, D., Willox, A. C., & Pearce, T. (2016). Including Indigenous knowledge and experience in IPCC assessment reports. *Nature Climate Change*, 6(4), 349-353. <https://doi.org/10.1038/nclimate2954>
- Fourage, A., Shepherd, C. R., Campera, M., Nekaris, K. A. I., & Nijman, V. (2022). It's a sign: Animal welfare and zoo type are predictors of animal identification signage usage and quality at zoo exhibits. *Zoo Biology*, 42(2), 283-295. <https://doi.org/10.1002/zoo.21734>
- Gagnon, C. A., & Berteaux, D. (2009). Integrating traditional ecological knowledge and ecological science: A question of scale. *Ecology and Society*, 14(2), 19. <https://doi.org/10.5751/ES-02923-140219>
- Goodwin, M. E. (2016). *Climate change education in the United States: An analysis of climate science inclusion in K-12 state science standards* [Doctoral dissertation, Evergreen State College].
- Haila, Y. (2000). Beyond the nature-culture dualism. *Biology and Philosophy*, 15(2), 155-175. <https://doi.org/10.1023/A:1006625830102>
- Hamalainen, P. (2019). *Lakota America*. Yale University Press. <https://doi.org/10.12987/9780300248746>
- Helmreich, S. (2009). *Alien ocean: Anthropological voyages in microbial seas*. University of California Press. <https://doi.org/10.1525/9780520942608>
- Hubbard, T. (2014). Buffalo genocide in nineteenth-century North America: "Kill, skin, and sell". In A. Laban Hinton, A. Woolford, & J. Benvenuto (Eds.), *Colonial genocide in indigenous North America* (pp. 292-305). Duke University Press. <https://doi.org/10.2307/j.ctv11sn770.17>
- Ito, T. (2014). *London zoo and the victorians, 1828-1859*. Boydell & Brewer Ltd.
- Kafai, Y., Searle, K., Martinez, C., & Brayboy, B. (2014, March). Ethnocomputing with electronic textiles: Culturally responsive open design to broaden participation in computing in American Indian youth and communities. In *Proceedings of the 45<sup>th</sup> ACM technical symposium on Computer science education* (pp. 241-246). ACM. <https://doi.org/10.1145/2538862.2538903>
- Kelly, L. A. D., Luebke, J. F., Clayton, S., Saunders, C. D., Matiasek, J., & Grajal, A. (2014). Climate change attitudes of zoo and aquarium visitors: Implications for climate literacy education. *Journal of Geoscience Education*, 62(3), 502-510. <https://doi.org/10.5408/13-078.1>
- Kiger, M. E., & Varpio, L. (2020). Thematic analysis of qualitative data: AMEE guide No. 131. *Medical Teacher*, 42(8), 846-854. <https://doi.org/10.1080/0142159X.2020.1755030>
- Kim, E. J. A., & Dionne, L. (2014). Traditional ecological knowledge in science education and its integration in grades 7 and 8 Canadian science curriculum documents. *Canadian Journal of Science, Mathematics and Technology Education*, 14, 311-329. <https://doi.org/10.1080/14926156.2014.970906>
- Kim, E.-J. A., Asghar, A., & Jordan, S. (2017). A critical review of traditional ecological knowledge (TEK) in science education. *Canadian Journal of Science, Mathematics and Technology Education*, 17, 258-270. <https://doi.org/10.1080/14926156.2017.1380866>
- Kimmerer, R. (2013). *Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants*. Milkweed Editions.
- Kress, J. S., & Elias, M. J. (2019). *Nurturing students' character: Everyday teaching activities for social-emotional learning*. Routledge. <https://doi.org/10.4324/9780429199875>
- Larocque, C., Foth, T., & Gifford, W. (2021). No more settler tears, no more humanitarian consternation: Recognizing our racist history and present NOW! *Witness: The Canadian Journal of Critical Nursing Discourse*, 3(1), 7-10. <https://doi.org/10.25071/2291-5796.107>
- Lewis, R. B., Jurmain, R., & Kilgore, L. (2013). *Understanding humans: Introduction to physical anthropology and archaeology*. Wadsworth.
- Lowan, G. (2012). Expanding the conversation: Further explorations into indigenous environmental science education theory, research, and practice. *Cultural Studies of Science Education*, 7(1), 71-81. <https://doi.org/10.1007/s11422-012-9379-1>
- Luebke, J. F., Clayton, S., Saunders, C. D., Matiasek, J., Kelly, L. A. D., & Grajal, A. (2012). Global climate change as seen by zoo and aquarium visitors. *Chicago Zoological Society*. <https://www.informalscience.org/global-climate-change-seen-zoo-and-aquarium-visitors>
- Macdonald, C., & Whiten, A. (2011). The 'living links to human evolution' research center in Edinburgh zoo: A new endeavor in collaboration. *International Zoo Yearbook*, 45(1), 7-17. <https://doi.org/10.1111/j.1748-1090.2010.00120.x>
- MacDonald, D. B., & Hudson, G. (2012). The genocide question and Indian residential schools in Canada. *Canadian Journal of Political Science/Revue Canadienne de Science Politique*, 45(2), 427-449. <https://doi.org/10.1017/S000842391200039X>
- Mack, E., Augare, H., Cloud-Jones, L. D., David, D., Quiver Gaddie, h., Honey, R. E., Kawagley, A. O., Little Plume-Weatherwax, M., Lone Fight, L., Meier, G., Pete, T., Rattling Leaf, J., Returns From Scout, E., Sachatello-Sawyer, B., Shibata, H., Valdez, S., & Wippert, R. (2012). Effective practices for creating transformative informal science education programs grounded in native ways of knowing. *Cultural Studies of Science Education*, 7, 49-70. <https://doi.org/10.1007/s11422-011-9374-y>
- Magallanes, C. J. I. (2015). Maori cultural rights in Aotearoa New Zealand: Protecting the cosmology that protects the environment. *Widener Law Review*, 21, 273.
- Maldonado, J. K., Colombi, B., & Pandya, R. (2016). *Climate change and indigenous peoples in the United States*. Springer.
- Marin, A., & Bang, M. (2015). Designing pedagogies for Indigenous science education: Finding our way to storywork. *Journal of American Indian Education*, 54(2), 29-51. <https://doi.org/10.1353/jaie.2015.a798550>

- Marshall, J. (2016). Exploring our interpretive practice: An impact evaluation. *International Zoo Educators Journal*, 52, 23-26.
- McKenzie, S. M. (2021). Acknowledging Canada's genocide. *Postcolonial Text*, 16(3).
- McKinley, E. (1996). Towards an indigenous science curriculum. *Research in Science Education*, 26(2), 155-167. <https://doi.org/10.1007/BF02356429>
- Meiers, N. J. (2010). *Designing effective field trips at zoos and aquariums*. <https://www.yumpu.com/en/document/view/11463528/designing-effective-field-trips-at-zoos-and-aquariums-middlab>
- Mengden IV, W. H. (2017). Indigenous people, human rights, and consultation: The Dakota access pipeline. *American Indian Law Review*, 41(2), 441-466.
- Milstein, T. (2009). "Somethin'tells me it's all happening at the zoo": Discourse, power, and conservationism. *Environmental Communication*, 3(1), 25-48. <https://doi.org/10.1080/17524030802674174>
- Miyake, S. (2017). Learning science in informal contexts. In *Science education* (pp. 431-442). Sense Publishers. [https://doi.org/10.1007/978-94-6300-749-8\\_31](https://doi.org/10.1007/978-94-6300-749-8_31)
- Munroe, E., Borden, L., Murray Orr, A., Toney, D., & Meader, J. (2013). Decolonizing aboriginal education in the 21<sup>st</sup> century. *McGill Journal of Education/Revue des Sciences de L'éducation de McGill*, 48(2), 317-337. <https://doi.org/10.7202/1020974ar>
- Nakashima, D., & Krupnik, I. (2018). *Indigenous knowledge for climate change assessment and adaptation*. Cambridge University Press. <https://doi.org/10.1017/9781316481066>
- NRC. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.
- Nygren, N. V., & Ojalampi, S. (2018). Conservation education in zoos: A literature review. *TRACE: Journal for Human-Animal Studies*, 4, 62-76. <https://doi.org/10.23984/fjhas.66540>
- Ocampo-Agudelo, J., & Maya, J. (2017). Experiential qualities of science museum exhibits: A thematic analysis. In *Proceedings of the 21<sup>st</sup> International Conference on Engineering Design* (pp. 439-448).
- Ogawa, M. (1995). Science education in a multisience perspective. *Science Education*, 79(5), 583-593. <https://doi.org/10.1002/sce.3730790507>
- Ogle, B. (2016). Can exhibits transform the adult visitor into the adult learner? *IZE Journal*, 52, 36-38.
- Oppenheimer, M. (2009). Using ICTs for indigenous cultural preservation: Challenges and strategies. *Ethnos Project*. <https://www.ethnosproject.org/using-icts-for-indigenous-cultural-preservation/>
- Pace, S., & Tesi, R. (2004). Adult's perception of field trips taken within grades K-12: Eight case studies in the New York Metropolitan Area. *Education*, 125(1).
- Packer, J., & Ballantyne, R. (2010). The role of zoos and aquariums in education for a sustainable future. *New Directions for Adult and Continuing Education*, 2010(127), 25-34. <https://doi.org/10.1002/ace.378>
- Paddle, R. N. (2000). *The last tasmanian tiger: The history and extinction of the thylacine*. Cambridge University Press.
- Patrick, P. G. (2014). The informal learning model: A sociocultural perspective of questioning pathways. *Journal of International Zoo Educators*, 50(2014), 35-38.
- Petzold, J., Andrews, N., Ford, J. D., Hedemann, C., & Postigo, J. C. (2020). Indigenous knowledge on climate change adaptation: A global evidence map of academic literature. *Environmental Research Letters*, 15(11), 113007. <https://doi.org/10.1088/1748-9326/abb330>
- Pieratos, N. A., Manning, S. S., & Tilsen, N. (2021). Land back: A meta narrative to help indigenous people show up as movement leaders. *Leadership*, 17(1), 47-61. <https://doi.org/10.1177/1742715020976204>
- Posthumus, D. C. (2016). A lakota view of Pté Oyáte (Buffalo nation). In *Bison and people on the North American great plains: A deep environmental history* (pp. 278-310).
- Putnam, W. (2012). "Please don't feed the natives": Human zoos, colonial desire, and bodies on display. *French Literature Series*, 39, 55-68. [https://doi.org/10.1163/9789401208840\\_005](https://doi.org/10.1163/9789401208840_005)
- Quigley, C. (2009). Globalization and science education: The implications for indigenous knowledge systems. *International Education Studies*, 2(1), 76-88. <https://doi.org/10.5539/ies.v2n1p76>
- Ray, A. J., & Conaty, G. T. (1998). I have lived here since the world began: An illustrated history of Canada's native people. *Canadian Ethnic Studies*, 30(1), 167.
- Redsteer, M. H., Kelley, K. B., Francis, H., & Block, D. (2013). *Increasing vulnerability of the Navajo people to drought and climate change in the southwestern United States: Accounts from tribal elders*. Cambridge University Press.
- Rennie, L., & McClafferty, T. (1995). Using visits to interactive science and technology centers, museums, aquaria, and zoos to promote learning in science. *Journal of Science Teacher Education*, 6(4), 175-185. <https://doi.org/10.1007/BF02614639>
- Rogers, E. S., & Smith, D. B. (1994). *Aboriginal Ontario: Historical perspectives on the first nations*. Dundurn.
- Rosalyn, N. (1991). The effects of residential schools on native child-rearing practices. *Canadian Journal of Native Education*, 18, 65-118.
- Roy, L. (2015). Indigenous cultural heritage preservation: A review essay with ideas for the future. *IFLA Journal*, 41(3), 192-203. <https://doi.org/10.1177/0340035215597236>
- Schwan, S., Grajal, A., & Lewalter, D. (2014). Understanding and engagement in places of science experience: Science museums, science centers, zoos, and aquariums. *Educational Psychologist*, 49(2), 70-85. <https://doi.org/10.1080/00461520.2014.917588>
- Singleton, B. E., Gillette, M. B., Burman, A., & Green, C. (2021). Toward productive complicity: Applying 'traditional ecological knowledge' in environmental science. *The Anthropocene Review*, 10(2), 393-414. <https://doi.org/10.1177/20530196211057026>

- Smith, N. (2006). Thank your mother for the rabbits: Bilbies, bunnies and redemptive ecology. *Australian Zoologist*, 33(3), 369-378. <https://doi.org/10.7882/AZ.2006.010>
- Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, 85(1), 6-34. [https://doi.org/10.1002/1098-237X\(200101\)85:1<6::AID-SCE3>3.0.CO;2-R](https://doi.org/10.1002/1098-237X(200101)85:1<6::AID-SCE3>3.0.CO;2-R)
- Sowards, S. K. (2006). Identification through orangutans: Destabilizing the nature/culture dualism. *Ethics and the Environment*, 11(2), 45-61. <https://doi.org/10.2979/ETE.2006.11.2.45>
- Statistics Canada. (2016). 2016 census. <https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/index-eng.cfm>
- Sutherland, D., & Swayze, N. (2012). The importance of place in Indigenous science education. *Cultural Studies of Science Education*, 7(1), 83-92. <https://doi.org/10.1007/s11422-011-9371-1>
- Tang, X., & Zhang, D. (2020). How informal science learning experience influences students' science performance: A cross-cultural study based on PISA 2015. *International Journal of Science Education*, 42(4), 598-616. <https://doi.org/10.1080/09500693.2020.1719290>
- Tzou, C., Meixi, Suárez, E., Bell, P., LaBonte, D., Starks, E., & Bang, M. (2019). Storywork in STEM-art: Making, materiality and robotics within everyday acts of indigenous presence and resurgence. *Cognition and Instruction*, 37(3), 306-326. <https://doi.org/10.1080/07370008.2019.1624547>
- Uggla, Y. (2010). What is this thing called 'natural'? The nature-culture divide in climate change and biodiversity policy. *Journal of Political Ecology*, 17(1), 79-91. <https://doi.org/10.2458/v17i1.21701>
- US Census Bureau. (2010). 2010 census. [https://www.census.gov/history/www/through\\_the\\_decades/overview/2010\\_overview\\_1.html](https://www.census.gov/history/www/through_the_decades/overview/2010_overview_1.html)
- Varpio, L., Young, M., Uijtdehaage, S., & Paradis, E. (2019). Articulating the distinctions between theory, theoretical framework, and conceptual framework. *Academic Medicine*, 95(7), 989-994. <https://doi.org/10.1097/ACM.00000000000003075>
- Visitor Demographics. (2019). Visitor demographics. AZA.org. <https://www.aza.org/partnerships-visitor-demographics?locale=en>
- Wagoner, B., & Jensen, E. (2010). Science learning at the zoo: Evaluating children's developing understanding of animals and their habitats. *Psychology & Society*, 3(1), 65-76.
- Wehi, P. M., Carter, L., Harawira, T. W., Fitzgerald, G., Lloyd, K., Whaanga, H., & MacLeod, C. J. (2019). Enhancing awareness and adoption of cultural values through use of Māori bird names in science communication and environmental reporting. *New Zealand Journal of Ecology*, 43(3), 1-9. <https://doi.org/10.20417/nzjcol.43.35>
- Wenzel, G. W. (2009). Canadian Inuit subsistence and ecological instability—If the climate changes, must the Inuit? *Polar Research*, 28(1), 89-99. <https://doi.org/10.1111/j.1751-8369.2009.00098.x>
- Whitney, G. G. (1996). *From coastal wilderness to fruited plain: A history of environmental change in temperate North America from 1500 to the present*. Cambridge University Press.
- Whyte, K. (2016a). Indigenous experience, environmental justice and settler colonialism. SSRN. <https://doi.org/10.2139/ssrn.2770058>
- Whyte, K. (2016b). Indigenous peoples, climate change loss and damage, and the responsibility of settler states. SSRN. <https://doi.org/10.2139/ssrn.2770085>
- Wysote, T., & Morton, E. (2019). 'The depth of the plough': White settler tautologies and pioneer lies. *Settler Colonial Studies*, 9(4), 479-504. <https://doi.org/10.1080/2201473X.2018.1541221>
- Yocco, V. S., Heimlich, J. E., Myers, C., & Jenike, S. D. (2010). Let's go to the zoo! Visitors' social expectations of a trip to the zoo. *International Zoo Education Journal*, 46, 36-40.
- Zidny, R., Sjöström, J., & Eilks, I. (2020). A multi-perspective reflection on how Indigenous knowledge and related ideas can improve science education for sustainability. *Science & Education*, 29(1), 145-185. <https://doi.org/10.1007/s11191-019-00100-x>